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Completely Positive Semidefinite Rank

A matrix X is called completely positive semidefinite (cpsd) if it can be represented as a Gram matrix of positive semidefinite matrices of some finite size d. The cpsd-rank of a cpsd matrix is the smallest integer d for which such a representation is possible. In this work, we initiate the study of the cpsd-rank which we motivate twofold. First, the cpsd-rank is a natural non-commutative analogue of the completely positive rank of a completely positive matrix. Second, we show that the cpsd-rank is physically motivated as it can be used to upper and lower bound the size of a quantum system needed to generate a quantum behavior. Unlike the completely positive rank which is at most quadratic in the size of the matrix, no general upper bound is known on the cpsd-rank. In fact, we show that the cpsd-rank can be exponential in terms of the size. The proof relies crucially on the connection between the cpsd-rank and quantum behaviors. In particular, we use a known lower bound on the size of matrix representations of extremal quantum correlations which we apply to high-rank extreme points of the n-dimensional elliptope.

This is joint work with Anupam Prakash, Antonios Varvitsiotis, and Zhaohui Wei (arXiv:1604.07199).